GUIDELINES AND TECHNICAL REQUIREMENTS FOR CONSTRUCTED WETLANDS FOR SECONDARY TREATMENT OF EFFLUENT IN LIVESTOCK WASTE MANAGEMENT SYSTEMS

Purpose and scope

These guidelines are intended to provide field personnel with basic information about planning and designing *constructed* wetlands as a component of livestock waste management systems.

Background

Wetlands normally fall into one of 4 categories:

Wetland restoration is defined as the rehabilitation of a degraded wetland or a hydric soil area that was previously a wetland.

Wetland enhancement is defined as improvement, maintenance, and management of existing wetlands for a particular function or value, possibly at the expense of others.

Wetland creation is defined as the conversion of a non-wetland area into a wetland where a wetland never existed.

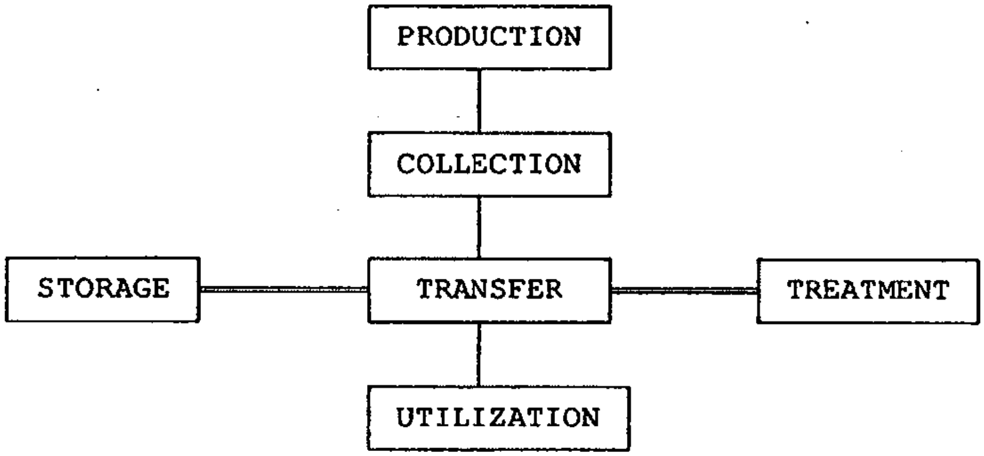
Constructed wetlands are specifically designed to treat both non-point and point sources of water pollution.

Wetlands are dynamic ecosystems, and three critical factors govern their viability: hydrology, soils/geomorphology, and vegetation.

Constructed wetlands, cont'd

Design considerations

The basic components of an adequate livestock waste management system, regardless of the type of animals is as follows:



COMPONENTS:
One or more constructed wetland cells may be added to the treatment component of the system. In swine systems, this should follow the one- or two-stage lagoon, and in dairy systems it should follow a lagoon. Following treatment in the constructed wetland cell(s), the effluent is utilized by discharging it onto a vegetated utilization area.

SIZE:
The system is sized according to engineering standards, using numbers of animals to calculate the amount of waste produced, and allowing for storm water reserve in the lagoon ahead of the wetland cells.

VEGETATION:
The wetland cells should be vegetated with species such as cattails, bulrush, reeds or rushes. For diversity, different cells in the same system could contain different species. As the cells mature species diversity will increase naturally.

CONSTRAINTS:
Water depth under normal conditions should be maintained within a range of 3 to 12 inches in the wetland cell. Maximum depth should not exceed 18 inches, and the depth should not exceed 12 inches for longer than 48 hours. The wetland cell shall be designed for a minimum 12 day residence time.

Constructed wetlands, cont'd

The outlet to the wetland cell should be constructed so as to allow complete dewatering of the wetland cell. This will allow for establishment of vegetation and periodic maintenance.

Minimum design criteria are given on the following pages.

WETLAND DESIGN

Step 1.

Compute daily BOD_5 to wetland as:

$$BOD_5\ (\text{lb./day}) = \frac{\text{dewatering vol. } (ft^3) \times BOD_5\ (\text{lb./}ft^3)}{\text{days to dewater}}$$

Livestock	Swine	Dairy	Beef	Poultry
BOD_5 lb/ft^3	.025	.022	.019	.045

Table 1. Typical BOD_5 Values for Anaerobic Lagoon Effluent

Step 2.

Assume a maximum loading rate of 65 lb. BOD_5/ac./day. Minimum wetland area is computed as:

$$\text{Acres Wetland} = \frac{\text{Actual Loading Rate (lb. } BOD_5\text{/day)}}{\text{Max. Loading Rate (lb. } BOD_5\text{/day/ac.)}}$$

Step 3.

Size the wetland to give required residence time. Residence time requirement in Bulletin 210-1-17 is twelve (12) days. The formula for computing residence time is:

$$t\ (\text{days}) = SA\ (ft^2) \times D\ (ft) \times P/Q\ (ft^3/\text{day})$$

where:

t = hydraulic residence time, days. "t" must equal or exceed 12 days.

SA = surface area of constructed wetland, ft^2.

D = flow depth in constructed wetland, ft. For design use flow depth = 0.5 ft.

Q = flow rate, ft^3/day. Flow rate is computed as (cubic feet to dewater)/(days to dewater).

P = porosity is the ratio of the volume of the constructed wetland occupied by water to the volume of the constructed wetland occupied by plants and water.

PLANT	POROSITY
Cattails (*Typha*)	0.95
Bulrush (*Scirpus validus*)	0.86
Reeds (*Phragmites*)	0.98
Rushes (*Juncus*)	0.95

Table 2. Acceptable Wetland Species and Porosities

The required treatment area may not be large enough to provide a hydraulic residence of 12 days. If "t" is less than 12 days, increase area to provide "t" of 12.

$$SA_{req}\ (ft^2) = \frac{SA\ (ft^2) \times 12\ \text{days}}{t_{computed}\ (\text{days})}$$

Step 4.

Configure the wetland. Ideally, a wetland will have a length to width ratio of 10:1. Required wetland width is computed as:

$$\text{Width (ft)} = [\ SA\ (ft^2)/\text{Length to Width Ratio}]^{1/2}$$

and length is Ratio x Width.

Utilization Area Design

A field utilization area shall be provided which can accomodate a volume of supernatant equal to the yearly dewatering volume without runoff (assuming 180 days to dewater) and can uptake the nitrogen from those waters in a growing season. If actual values for N concentration in lagoon supernatant are not available, use values in Table 3.

Livestock	Swine	Dairy	Beef	Poultry
TKN (lb/ft_3)	.022	.013	.013	.038

Table 3. Typical TKN Values for Anaerobic Lagoon Effluent

Step 1.

Determine acreage(s) required to utilize all nitrogen present in lagoon effluent. Compute acreage required as:

$$\text{Util. Area (ac)} = \frac{\text{Dewatering Vol. } (ft^3) \times \text{TKN } (lb/ft^3)}{\text{Crop N Uptake (lb/acre)}}$$

Step 2.

Compute dewatering rate as:

$$\text{Dewatering Rate } (ft^3/day) = \frac{\text{Dewatering Vol. } (ft^3)}{\text{Days to Dewater}}$$

Step 3.

Check the soils in the utilization area to assure their ability to infiltrate effluent is adequate. The infiltration rate of the utilization area needs to exceed:

$$I_{min} = \frac{\text{Daily Dewatering Vol } (ft^3) \times 12 \text{ (in/ft)}}{24 \text{ (hrs/day)} \times 43{,}560 \ ft^2/\text{acre}}$$

Actual Infiltration Rate = ____________ in/hr

If the required infiltration rate exceeds the actual rate, multiply the acreage required for utilization by:

$$\text{Infiltration Coeficient} = \frac{\text{Required Infiltration Rate}}{\text{Actual Infiltration Rate}} = C_I$$

$$\text{Revised Util. Area (ac)} = \text{Util. Area (ac)} \times C_I$$

OTHER CONSIDERATIONS

The lagoon shall be outletted by an active (not passive) system capable of delivering supernatants to wetlands and/or the field utilization area at rates dictated by the design. As a minimum, a system of valves or gates shall be incorporated into the system which allow for:

1. Regulation of liquid levels in lagoon(s) between the elevation which represents minimum treatment volume and the elevation which leaves only storage for the 25 year, 24 hour storm with one foot of freeboard.

2. Dewatering of lagoon(s) through wetland(s) or to the waste utilization area in not longer than 180 days.

3. Maintaining design water levels in wetland(s) and dewatering wetland(s) in not less than 12 days.

The landowner/operator shall include as a component of the Waste Management System Plan provisions for complete agitation and emptying of the lagoon(s), including sludge accumulation for the design sludge storage interval. That component of the plan shall include:

1. Equipment needed for agitating, emptying and hauling/flowing lagoon liquids and solids.

2. Days required to empty lagoon(s).

3. Acres of cropland for utilization.

4. Location of utilization area(s).

Provisions shall be made for agitating and pumping all wastes from the lagoon at intervals dictated by the design. Those wastes shall be disposed of/utilized as per SCS Standard and Specification 633, Waste Utilization.

Sources Cited

Cathcart, T., Sugeng Triyono, Jonathan Pote, and Mark Crenshaw, Performance of a Constructed Wetland Used for Swine Wastewater Treatment (Presented at Workshop on Constructed Wetlands for Animal Waste Management, April 1994, Lafayette, Indiana, USA)

Hammer, Donald A., Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, Agricultural (Proceedings of the First International Conference on Constructed Wetlands for Wastewater Treatment) Lewis Publishers, Inc. 1989, Chelsea, MI, USA

McCaskey, T. A., S. N. Brett, T. C. Hannah, V. W. E. Payne and J. T. Eason, Treatment of Swine Lagoon Effluent by Constructed Wetlands Operating at Three Loading Rates (Presented at Workshop on Constructed Wetlands for Animal Waste Management, April 1994, Lafayette, Indiana, USA)

Sikora, F. J., Summary of Research at the Tennessee Valley Authority's Constructed Wetlands Research and Development Facility (Presented at Workshop on Constructed Wetlands for Animal Waste Management, April 1994, Lafayette, Indiana, USA)

Skarda, S. M., J. A. Moore,S. F. Niswander and M. J. Gamroth, Preliminary Results of Wetland for Treatment of Dairy Wastes (Presented at Workshop on Constructed Wetlands for Animal Waste Management, April 1994, Lafayette, Indiana, USA)

United States Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Part 651, Agricultural Waste Management Field Handbook, April 1992

WETLAND DESIGN

EXAMPLE PROBLEM: A well established and operated lagoon for a swine operation has waste + dilution water storage of 100,000 cubic feet. What would be the daily loading rate to a wetland below that lagoon? Dewater in 180 days.

Step 1.

Compute daily BOD_5 to wetland as:

$$BOD_5 \text{ (lb./day)} = \frac{\text{dewatering vol. (ft}^3\text{) x } BOD_5 \text{ (lb./ft}^3\text{)}}{\text{days to dewater}}$$

$$= \frac{(\quad 100{,}000 \quad) \times (\quad 0.025 \quad)}{(\quad 180 \quad)}$$

$$= \quad 13.9 \quad \text{lb./day}$$

Livestock	Swine	Dairy	Beef	Poultry
BOD_5 lb/ft^3	.025	.022	.019	.045

Table 1. Typical BOD_5 Values for Anaerobic Lagoon Effluent

Step 2.

Assume a maximum loading rate of 65 lb. BOD_5/ac./day. Minimum wetland area is computed as:

$$\text{Acres Wetland} = \frac{\text{Actual Loading Rate (lb. } BOD_5\text{/day)}}{\text{Max. Loading Rate (lb. } BOD_5\text{/day/ac.)}}$$

$$= \frac{(\quad 13.9 \quad)}{(\quad 65 \quad)} = \quad 0.2 \quad \text{Acres}$$

Step 3.

Size the wetland to give required residence time. Residence time requirement in Bulletin 210-1-17 is twelve (12) days. The formula for computing residence time is:

t (days) = SA (ft^2) x D (ft) x P/Q (ft^3/day)

where:

t = hydraulic residence time, days. "t" must equal or exceed 12 days.

SA = surface area of constructed wetland, ft^2.

D = flow depth in constructed wetland, ft. For design use flow depth = 0.5 ft.

Q = flow rate, ft^3/day. Flow rate is computed as (cubic feet to dewater)/(days to dewater).

P = porosity is the ratio of the volume of the constructed wetland occupied by water to the volume of the constructed wetland occupied by plants and water.

PLANT	POROSITY
Cattails (*Typha*)	0.95
Bulrush (*Scirpus validus*)	0.86
Reeds (*Phragmites*)	0.98
Rushes (*Juncus*)	0.95

Table 2. Acceptable Wetland Species and Porosities

EXAMPLE PROBLEM: The wetland cells will be populated with rushes - P = 0.95.

t (days) = SA (ft^2) x D (ft) x P/Q (ft^3/day)

= (8712) x (0.5) x (0.95 / 555)

= 7.5 days

The required treatment area may not be large enough to provide a hydraulic residence of 12 days. If "t" is less than 12 days, increase area to provide "t" of 12.

EXAMPLE PROBLEM: While the 8712 square feet is large enough for treating BOD_5 it will not provide 12 days residence time. Increase the area to provide 12 days.

$$SA_{req} = \frac{SA\ (ft^2) \times 12\ \text{days}}{t_{computed}\ (\text{days})} = 13939\ ft^2$$

Step 4.

Configure the wetland. Ideally, a wetland will have a length to width ratio of 10:1. Required wetland width is computed as:

$$\text{Width (ft)} = [\ \text{SA (ft}^2\text{)/Length to Width Ratio}]^{1/2}$$

$$\text{Width} = (\ 13939\ /\ 10\ )^{1/2} = 38\ \text{ft}$$

and length is Ratio x Width.

$$\text{Length} = (\ 38\ ) \times (\ 10\ ) = 380\ \text{ft.}$$

Utilization Area Design

A field utilization area shall be provided which can accomodate a volume of supernatant equal to the yearly dewatering volume without runoff (assuming 180 days to dewater) and can uptake the nitrogen from those waters in a growing season. If actual values for N concentration in lagoon supernatant are not available, use values in Table 3.

EXAMPLE PROBLEM: The landowner/operator wishes to utilize the effluent from the lagoon/wetland on corn grain acreage. Average yield is 150 bushels per acre. Assume that the corn grain removes 1 pound of nitrogen per bushel. Assume that all effluent may be pumped from lagoon and that average TKN is .022 lb/ft^3.

Livestock	Swine	Dairy	Beef	Poultry
TKN (lb/ft_3)	.022	.013	.013	.038

Table 3. Typical TKN Values for Anaerobic Lagoon Effluent

Step 1.

Determine acreage(s) required to utilize all nitrogen present in lagoon effluent. Compute acreage required as:

$$\text{Util. Area (ac)} = \frac{\text{Dewatering Vol. (ft}^3\text{) x TKN (lb/ft}^3\text{)}}{\text{Crop N Uptake (lb/acre)}}$$

$$= \frac{(\ 100{,}000\ )\ \text{x}\ (\ 0.022\ )}{(\ 150\ )} = 14.7\ \text{ac}$$

Step 2.

Compute dewatering rate as:

$$\text{Dewatering Rate (ft}^3\text{/day)} = \frac{\text{Dewatering Vol. (ft}^3\text{)}}{\text{Days to Dewater}}$$

$$= \frac{(\ 100{,}000\ )}{(\ 180\ )} = 555\ \text{ft}^3\text{/day}$$

Step 3.

Check the soils in the utilization area to assure their ability to infiltrate effluent is adequate. The infiltration rate of the utilization area needs to exceed:

$$I_{min} = \frac{\text{Daily Dewatering Vol (ft}^3\text{) x 12 (in/ft)}}{\text{24 (hrs/day) x 43,560 ft}^2\text{/acre x Acres}}$$

$$= \frac{(\ 6660\ )}{(87{,}120\ \text{x}\ 14.7)} = 0.005\ \text{in/hr}$$

EXAMPLE PROBLEM: Soils at the utilization site are moderately slowly permeable, with an infiltration rate exceeding 0.2 inches per hour.

Actual Infiltration Rate = 0.2 in/hr

EXAMPLE PROBLEM: Actual site permeability is much more than required.

= ( ) x ( ) = ______________ ac

WETLAND DESIGN

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Compute daily BOD_5 to wetland as:

$$BOD_5 \text{ (lb./day)} = \frac{\text{dewatering vol. (ft}^3) \times BOD_5 \text{ (lb./ft}^3)}{\text{days to dewater}}$$

$$= \frac{(\qquad\qquad) \times (\qquad\qquad)}{(\qquad\qquad)}$$

$$= \underline{\qquad\qquad\qquad} \text{ lb./day}$$

Livestock	Swine	Dairy	Beef	Poultry
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$$= \frac{(\qquad\qquad)}{(\qquad\qquad)} = \underline{\qquad\qquad} \text{ Acres}$$

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= (   ) x (   ) x (/   )

= __________ days

The required treatment area may not be large enough to provide a hydraulic residence of 12 days. If "t" is less than 12 days, increase area to provide "t" of 12.

$$SA_{req} = \frac{SA\ (ft^2) \times 12\ days}{t_{computed}\ (days)} = \_\_\_\_\_\_\_\_\_\_ ft^2$$

Step 4.

Configure the wetland. Ideally, a wetland will have a length to width ratio of 10:1. Required wetland width is computed as:

Width (ft) = [SA (ft^2)/Length to Width Ratio]$^{1/2}$

Width = (/   )$^{1/2}$ = ______________ ft

and length is Ratio x Width.

Length = (   ) x (   ) = ______________

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$$= \frac{(\qquad\qquad) \times (\qquad\qquad)}{(\qquad\qquad)} = \underline{\qquad\qquad} \text{ ac}$$

Step 2.

Compute dewatering rate as:

$$\text{Dewatering Rate } (ft^3/day) = \frac{\text{Dewatering Vol. } (ft^3)}{\text{Days to Dewater}}$$

$$= \frac{(\qquad\qquad)}{(\qquad\qquad)} = \underline{\qquad\qquad} \ ft^3/day$$

Step 3.

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$$= \frac{(\qquad\qquad)}{87{,}120} = \_\_\_\_\_\_\_\_\_\_ \text{ in/hr}$$

Actual Infiltration Rate = __________ in/hr

If the required infiltration rate exceeds the actual rate, multiply the acreage required for utilization by:

$$\text{Infiltration Coeficient} = \frac{\text{Required Infiltration Rate}}{\text{Actual Infiltration Rate}} = C_I$$

Revised Util. Area (ac) = Util. Area (ac) x C_I

= (   ) x (   ) = __________ ac